GROUP IV NANOPARTICLE JUNCTIONS AND DEVICES THEREFROM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Pat. App. No. 60/969,887 entitled METHODS AND APPARATUS FOR CREATING JUNCTIONS ON A SUBSTRATE, and filed Sep. 4, 2007, which is incorporated by reference.

FIELD OF DISCLOSURE

[0002] This disclosure relates in general to nanoparticles and in particular to Group IV nanoparticle junctions and devices therefrom.

BACKGROUND

[0003] Semiconductors form the basis of modern electronics. Possessing physical properties that can be selectively modified and controlled between conduction and insulation, semiconductors are essential in most modern electrical devices (e.g., computers, cellular phones, photovoltaic cells, etc.). Group IV semiconductors generally refer to those elements in the fourth column of the periodic table (e.g., carbon, silicon, germanium, etc.).

[0004] In general, a solid semiconductor tends to exist in three forms: crystalline, polycrystalline, and amorphous. In crystalline form, semiconductor atoms are positioned in a single unbroken crystal lattice with no grain boundaries. In polycrystalline form, the semiconductor atoms are positioned in many smaller and randomly oriented crystallites (smaller crystals). The crystallites are often referred to as grains. In amorphous form, the semiconductor atoms show no long-range positional order.

[0005] Conduction generally refers to the movement of electrically charged carriers, such as electrons or holes (a lack of electrons), through electromagnetic fields. Metals tend to have substantial amounts of electrically charged particles available, whereas insulators have very few.

[0006] In the absence of impurities (called dopants), a semiconductor tends to behave as insulator, inhibiting the flow of an electric current. However, after the addition of relatively small amounts of dopants, the electrical characteristics of a semiconductor can dramatically change to a conductor by increasing the amount of electrically charged carriers. For example, in a process called photoexcitation, absorbed light will generally create an electron-hole pair (photocarriers) that in turn tends to increase overall conductivity (photoconductivity).

[0007] Depending on the kind of impurity, a doped region of a semiconductor can have more electrons (n-type) or more holes (p-type). For example, in a common configuration, a p-type region is placed next to an n-type (counter doped) region in order to create a (p-n) junction with a “built-in” potential. That is, the energy difference between the two Fermi levels.

[0008] Under generally accepted principals of quantum mechanics, electrons of an atom can only reside in certain states, so that only particular energy levels are possible. However, the occupation of particular energy states cannot be determined with particularity. Consequently, for an assemble of atoms (e.g., solid) a probability distribution or density is commonly used, called the Fermi level. In general, the Fermi level describes the energy level at given temperature in which ½ of the energy states are filled. Energy states are unique and correspond to a quantum number.

[0009] Consequently, electrons on the p-type side of the junction within the electric field may then be attracted to the n-type region and repelled from the p-type region, whereas holes within the electric field on the n-type side of the junction may then be attracted to the p-type region and repelled from the n-type region. Generally, the n-type region and/or the p-type region can each respectively be comprised of varying levels of relative dopant concentration, often shown as n−, n+, n++, p−, p+, p++, etc. The built-in potential and thus magnitude of electric field generally depend on the level of doping between two adjacent layers.

[0010] In another typical configuration, a junction may be created by placing an intrinsic (undoped) semiconductor layer (i-type) between the n-type region and the p-type region in order to mitigate the effects of quantum tunneling, a quantum-mechanical effect in which an electron transitions through a classically-forbidden energy state. In general, in a depletion region, the generated electromagnetic field is the result of the built-in potential and the applied reverse bias, divided by the depletion width. However, built-in potential is also inversely proportional to the defect density of the depletion region. Consequently, for materials having high defect density (i.e., undesirable energy states) tunneling may occur.

[0011] Thus, an i-type region with a lower defect density may be used to minimize tunneling. That is, lower the defect density. For example, without an intrinsic separation layer, if the p-n junction is sufficiently narrow, a high electromagnetic field may generate a tunneling current in the same direction as the electromagnetic field. That is, tunneling electrons may travel directly from the valence band of the p-type region into the conduction band of the n-type region. In contrast, if the p-n junction was ideal, there would be no current because there are no carriers for the electromagnetic field to draw.

[0012] In yet another typical configuration, a metal junction may be created by placing a heavily doped n-type region (n++) or a p-type region (p++) next to a metal region in order to form an ohmic (low-resistance) contact. In general, placing a doped region next to a metal creates a potential barrier at the junction. However, increasing the dopant concentration also tends to narrow the depletion region, which in turn tends to create a higher electromagnetic field, and thus a higher quantum tunneling probability. In addition, increasing the dopant concentration also tends to increase the probability that at least some of the charge carriers (electrons or holes) have enough thermal energy to jump over the potential barrier and cross into the metal region to become current.

[0013] There are several methods of doping a semiconductor. However, most of these may be problematic. For example, a common method involves depositing a doped glass on a semiconductor substrate via a silk-screen. A printing technique that makes use of a squeegee, silk-screening mechanically forces a liquid, such as a highly doped glass paste, directly onto a substrate. Once exposed to relatively high temperature (e.g., 800-1100° C.), the dopants tend to diffuse from the highly-doped glass into the substrate. The high temperature will also tend to anneal the substrate.

[0014] Annealing is generally the process of heating a material above a certain critical temperature in order to reduce the materials internal stresses, and or improve its physical and electrical properties. In the case of a semicon-